Organic Reactions

Key Concepts

This lesson will focus on the following:

- Substitution reaction
- Combustion
- Hydrogenation
- Halogenation
- Hydrohalogenation
- Hydration
- Elimination reaction

Terminology & definitions

- Substitution reaction – is a chemical reaction in which an atom or a group of atoms in a molecule are replaced or substituted by another atom or group of atoms.
- Combustion – is a chemical reaction in which a substance reacts rapidly with oxygen and produces heat and light.
- Addition reaction – is a chemical reaction where a molecule attaches to the double or triple bond of a second molecule to form a single molecule. During the reaction the double or triple bond is broken and new atoms are added to the molecule to form a more saturated product.
- Hydrogenation – is the addition reaction that takes place when hydrogen gas(H_2) is added to an unsaturated hydrocarbon (alkenes or alkynes) in the presence of a suitable catalyst (e.g. Ni, Pt or Pd).
- Halogenation – is the addition reaction that takes place if a halogen is added to an unsaturated hydrocarbon.
- Hydrohalogenation – is the addition of anhydrous hydrogen halides to produce alkyl halides.
- Hydration – is the addition of water in an unsaturated hydrocarbon in the presence of a catalyst to produce an alcohol.
- Elimination reaction – is the removal of a small molecule from a big molecule.

X-planation of key concepts and terminologies

Substitution

A substitution reaction is a chemical reaction in which an atom or group of atoms in a molecule are replaced or substituted by another atom or group of atoms. The process of substitution is only possible under two conditions, in the presence of sunlight or ultra-violet light and at a temperature between 250^0C and 450^0C. In the alkanes the hydrogen atom is displaced by a halogen atom to form two products of which one is a haloalkane/alkyl halide. This reaction is thus called substitution reaction through the process of halogenation.

$$CH_4(g) + Cl_2(g) \xrightarrow[\Delta]{hf} CH_3Cl(g) + HCl(g)$$

Combustion

Combustion is a chemical reaction in which a substance reacts rapidly with oxygen and produces heat and light. All combustion reactions are exothermic. Hydrocarbons undergo combustion to form $CO_2(g)$ and $H_2O(g)$.

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g) + \text{energy}$$

$$2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O + \text{energy}$$

Addition

Unsaturated compounds undergo addition reactions to form saturated compounds. When a double or triple bond breaks, other atoms are added to the chain. Addition reactions, which occur at unsaturated hydrocarbons, happen faster than substitution reactions which occur at saturated hydrocarbons, and this difference in rate can be used to test whether a hydrocarbon is saturated or unsaturated.

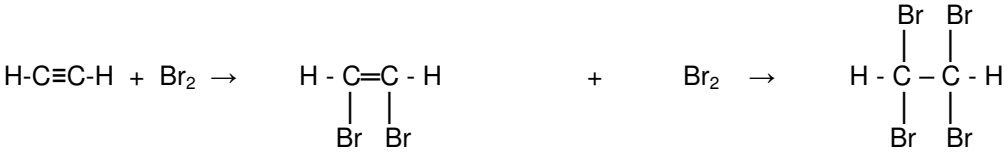
Hydrogenation

Hydrogenation is the addition reaction that takes place when hydrogen gas (H_2) is added to an unsaturated hydrocarbon in the presence of a suitable catalyst (e.g. Ni, Pt, or Pd). It is used in producing margarine.

$$CH_2 = CH_2 + H_2 \rightarrow CH_3 - CH_3$$

Halogenation

Halogenation is the addition of halogens X_2 (X = Cl, Br, I).



Hydrohalogenation

Hydrohalogenation, is the addition of HX (X = Cl, Br, I) in the presence of water.

$$CH_2 = CH_2 + HCl \rightarrow CH_3 - CH_2Cl$$

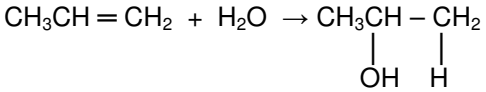
During addition of HX to unsaturated hydrocarbon, the H atom attaches to the C atom which already bears the greater number of H atoms. The X atom attaches to the C atom bearing the smaller number of H atoms.

Hydration

Hydration is the addition of water to a hydrocarbon in the presence of a catalyst.

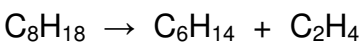
$$CH_2 = CH_2 + H_2O \rightarrow CH_3\text{-}CH_2OH$$

During addition of H-OH to unsaturated hydrocarbons, the H atom attaches to the C which already bears the greater number of H atoms. The OH group attaches to the C atom bearing the smaller number of H atoms.



Elimination

Elimination implies the removal of a smaller molecule out of a larger molecule. Cracking of alkanes is an example of elimination reaction. Cracking is when molecules with large molecular masses are broken into molecules with smaller molecular masses.



X-ample Questions

1. Show how chloromethane, dichloromethane, trichloromethane and tetrachloromethane are formed through substitution reaction between methane and chlorine.

2. Make use of structural formulae to show the reaction between bromomethane and water.

3. Make use of structural formulae to show:
   3.1 the reaction between ethane and chlorine.
   3.2 the reaction between propyne and bromine.

4. Show how the following molecules can be formed through hydrogenation:
   4.1 propane
   4.1 ethene
   4.2 ethane

5. Show how the following molecules can be formed through halogenation.
   5.1 1,2-dibromoethane
   5.2 1,2-dibromoethene
   5.3 1,1,2,2-tetrabromoethane

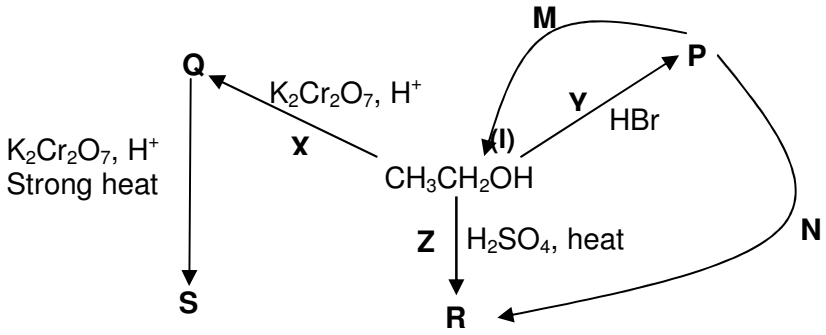
6. Show how water and ethene combine in the presence of a catalyst to produce ethanol.

7. Make use of structural formulae to show the reaction between ethane and hydrogen iodide.

8. Show the formation of ethane through …
   8.1 the action of potassium hydroxide on bromoethane.
   8.2 dehydration of ethanol.

X-ercise

The flowchart below shows different conversions that can be done between organic compounds. P, Q, R, and S represent organic compounds. X, Y and Z represent types of chemical reactions. M and N represent the conversion from the one compound to the next.



1.1 What is meant by the term "homologous series"?

1.2 To which homologous series does molecule **(I)** belong to.

1.3 What type of reaction is represented by X?

1.4 Which property of potassium dichromate makes it suitable to act as a reactant, in reaction X?

1.5 What special name is given to the elimination reaction represented by Z?

1.6 Briefly explain how the conversion indicated by M can be brought about.

1.7 What special name is given to the conversion represented by N?

1.8 Classify Y as an addition or a substitution reaction.

1.9 Briefly explain how compound R can be converted into ethanol.

Answer

1.1 Compounds with the same functional group, that can be described by the same general formula or consecutive members differ by a – CH_2 group.

1.2 Alcohols.

1.3 Redox reaction (oxidation of alcohol, reduction of oxygen).

1.4 strong oxidising agent.

1.5 dehydration.

1.6 Treat the haloalkane, mixed with ethanol, with a watery NaOH solution.

1.7 dehydrohalogenation.

1.8 substitution reaction.

1.9 Acid catalysed hydration of ethene – addition of water in the presence of H_3PO_4 as catalyst at a high temperature.